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METAL CERAMIC (POWDER METALLURGICAL) MATERIALS AND HARD ALLOYS USED IN SOVIET MACHINE BUILDING

Ye. A. Chudakov

[Tables referred to are appended.]

I. METAL CERAMIC MATERIALS AND PRODUCTS

Metal ceramic materials and products are made from various powdered metals, or from mixtures of these substances with nonmetallic powders such as powdered graphite, silica, or asbestos.

The types and uses of the most common metal ceramic materials and products are as follows:

Type	Use
Antifriction	Sleeve bearings
Porous	Filters; heat-resistant, gas-permeable foundry molds
Friction	Brake disks and linings with an iron or copper base
Electrical engineering	Contacts for spot and roll welding, and contacts for various instruments and electric furnaces; magnets; cores; metal-carbon contacts
Dense	Various machine parts
Refractory	Filament wire in electric light bulbs and contacts, medical instruments, and radio engineering equipment

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Properties of Metal Ceramic Materials

The properties of porous metal ceramic materials are intermediate between the properties of pressed and compact metals. The basic factor affecting the properties of metal ceramic products is their porosity.

A peculiar feature of metal ceramic materials is the lack of the proportional relationship between hardness, compression strength, and tensile strength which is characteristic of cast materials.

The compression strength of metal ceramic materials often equals or even exceeds that of cast material of the same composition, whereas the tensile strength is considerably lower.

Another peculiarity of porous metal ceramic materials is their combination of a high degree of friability under tension and of plasticity under compression. This feature is due to incomplete contact between the parts of which the sintered materials are composed.

With a one-percent decrease in porosity, the mechanical properties of metal ceramic materials show an increase of 3-10 percent.

The mechanical properties of materials made from coarse powders are lower than those of materials made of fine powders, these properties being diminished with an increase in the number of components of the materials.

(Data on the mechanical properties of porous sintered iron are given in Table 1.)

The diversity of pores depends on the nature of the powders and the particle size. The most common types of pores are (1) the enclosed -- like bubbles, with no intercommunication; (2) tubular -- elongated and intercommunicating; (3) pocket shaped -- coarse pores of the closed type; and (4) micropores -- dispersed through the entire compact.

Certain technological properties of dense (nonporous) metal ceramic materials are indistinguishable from those of pressure cast metals. In some cases the properties are even intensified. For example, metal ceramic steel, produced from carbonyl iron powder, can be welded much better than cast steel.

Dense metal ceramic products are made for the most part with a base of iron, copper, aluminum, or their alloys.

Powder metallurgical methods make it possible to manufacture widely different parts with a high degree of precision. Data on the chief properties of dense sintered materials are given in Table 2.

By powder metallurgical methods a .7- to .9-percent carbon steel can be obtained, which has the following properties: impact strength, 200-300 kilogram-meters per square centimeter; tensile strength, 45-60 kilograms per square millimeter; and Rockwell hardness, A scale, above 65. Table 2 gives the chief properties of metal ceramic materials.

Technical Characteristics of the Most Important Types of Metal Ceramic Materials

1. Antifriction Materials

This group includes porous bronze-graphite and iron-graphite bearings. The technical description of the most important types of porous bearings are given in Table 3.

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The basic distinguishing features of porous bearings are as follows: (a) A Brinell hardness of 25-45, which permits use of the bearings for both raw and hardened shafts. (b) The properties of bearings with an iron base are almost unchanged when they are heated to 200 degrees centigrade. (c) The coefficient of thermal expansion of porous bearings differs little from the coefficient of expansion of cast bearings. (d) The coefficient of friction, with flood lubrication, is less than with bearings of cast tin bronze. The coefficient of friction decreases with an increase in the load on the bearing. At low peripheral speeds (within one meter per second), the coefficient of friction first decreases with an increase in peripheral speed, then increases somewhat, and at speeds of more than 2 meters per second begins slowly to fall again. (e) Porous bearings are more wear-resistant than cast bearings because of the absence of dry friction. Porous iron-graphite bearings, for example, wear six times as well as babbitt B-83 bearings. In running-in properties, porous bearings are equal and in some cases even superior to babbitt B-83 bearings.

The permissible load on porous bearings depends mainly on their chemical composition, the particle size of the initial material (the powders), the peripheral speed, and the type of lubrication. Table 4 shows the results of tests on porous bearings.

Comparative tests on different types of bearings at TsNIITMASh (Central Scientific Research Institute of Technology and Machine Building) with drop lubrication (80 drops per minute), at a peripheral speed of 2.2 meters per second, showed the following PV values in kilogram-centimeters per second: 222 for babbitt B-83, 53 for cast bronze, 84 for porous iron-graphite, and 39 for porous bronze.

For the porous iron-graphite bearings developed by TsNIITMASh, the PV value amounts to 200-250 kilogram-centimeters per second.

With PV values up to 40 kilogram-centimeters per second, porous bearings impregnated with oil require no additional lubrication, but when the PV value is above 40 kilogram-centimeters per second, supplementary lubrication is necessary.

2. Metal Ceramic Filters

Metal ceramic filters are made chiefly from bronze, less often from nickel, brass, or silver. They range in size from 2 to 300 millimeters for cylindrical filters, and up to 500 x 1,200 millimeters for filter plates.

With metal ceramic filters, the filtration speed of gasoline varies from 30 to 60 liters per minute per square centimeter of filtering surface, with pressure changes within .5-2.5 kilograms per square centimeter.

The tensile strength of bronze filters is 3-4 kilograms per square millimeter; elongation is 2.8-3 percent; porosity, 45-50 percent (by volume); and minimum wall thickness, 1.5-3 millimeters.

Metal ceramic filters are used for separating a small quantity of solid impurities from a large quantity of liquid.

The maximum permissible temperature of the filtering liquid is 500 degrees centigrade if the filter is oxidation-resistant; otherwise, it is 180 degrees.

3. Friction Materials

The technical description of friction materials are given in Table 5.

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4. Contact Materials

Metal ceramic materials are used for welding contacts (for roll and spot welding), sparking contacts, and contacts for various switching devices (knife switches, relays, etc.).

The chemical composition of metal ceramic contact materials varies widely. The basic components are tungsten, copper, molybdenum, chromium, cadmium, zinc, cadmium oxide, silver, and nickel. The chief types of contacts are the following: tungsten (100 percent W); copper-tungsten (50-70 percent W); silver-tungsten (50-70 percent W); copper-molybdenum (50-70 percent Mo); silver-molybdenum (50-70 percent Mo); copper-nickel-tungsten (80-95 percent W, 2-10 percent Cu, 2-10 percent Ni); tungsten carbide (90-98 percent WC, and the remainder Co or Os; and silver-base contacts, including silver-graphite (5-25 percent graphite); silver-cadmium (2.5-10 percent CdO); and silver-nickel (10-60 percent Ni).

A description of the most important properties of metal ceramic contacts is given in Table 6.

The erosion resistance of metal ceramic contacts is many times as great as that of copper contacts. Metal ceramic contacts can therefore be used successfully in various types of sparking devices. The durability of metal ceramic welding contacts is also considerably greater than that of copper contacts, as shown in Table 7.

5. Metal-Graphite Brushes

Metal-graphite brushes for electric motors are made from a mixture of copper and graphite. Their most significant properties are shown in Table 8.

6. Metal Ceramic Magnetic Materials

These include (1) magnetic-dielectric alloys such as alsifer (an alloy of aluminum, silicon, and iron) and alnico (an alloy of aluminum, nickel, and cobalt), which are pressed metallic, ferromagnetic powders, the particles of which are insulated with dielectrics, usually Bakelite; and (2) magnetic materials for high-frequency currents, made from powders of carbonyl iron and nickel.

The chemical composition and physical properties of metal ceramic magnetic materials are given in Table 9.

Metal ceramic magnets are used in telephone sets, relays, radio-location instruments, and many other instruments.

7. Metal Ceramic Structural Materials

Powder metallurgical methods are used to make metal ceramic structural materials and products from bronze; carbon, stainless, and high-speed steel; aluminum and zinc alloys; and many other metals and alloys. Table 10 gives a description of the most important metal ceramic structural materials.

8. Refractory Metals

These include tungsten, molybdenum, tantalum, niobium, zirconium, vanadium, thorium, hafnium, etc.

Tungsten, in the form of wire or sheet, is used in the production of electric light bulbs, contacts in medical instruments, magnetos, etc. Molybdenum wire is used to make supporting parts for electric light bulbs. Tantalum and

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niobium are used in sheet form in the production of surgical and special corrosion-resistant apparatus, as well as for the manufacture of spinnerets for the production of rayon. Zirconium and vanadium are used in the form of powders and alloys with iron and other metals to obtain special heat-resistant alloys. The properties of tungsten, molybdenum, and tantalum are shown in Table 11.

Basic Principles for Selection of Metal Ceramic Products

In developing the design of a machine or apparatus, the question of the efficiency of using metal ceramic products, instead of products produced by the usual methods from a dense metal, can be determined by considering the following conditions:

1. Conditions which contribute to the occurrence of compressing stresses (narrow projections, sharp spikes, etc.) are inadmissible for metal ceramic products.

2. The relationship of the height of an object to its diameter must not exceed 2.5, and the relationship of the height to the wall thickness should not exceed 15-17. The maximum accuracy attainable is second class.

II. HARD ALLOYS

General Description

The hard alloys used in machine building are metal ceramic or fused. Metal ceramic hard alloys are used for making the working parts of dies and tools used in cutting and drawing metal; for drilling rock, etc. Fused hard alloys are used for building up the wearing parts of mechanisms and machines, and dies and attachments, to increase their wear-resistance.

Metal ceramic hard alloys produced are tungsten and titanium-tungsten alloys, with cobalt used as a bond for the carbides. Fused hard alloys may be subdivided into stellite, quasi-stellite, granular, and electrode types.

Stellites are cast, fused alloys of cobalt, chromium, tungsten, and carbon, and are produced mainly in the form of rods which are used as electrodes for gas welding. The quasi-stellite fused alloys (iron, chromium, nickel, and carbon) closely resemble the stellites in properties and structure, but they have a different chemical composition. The granular fused alloys (vokar and stalinite) are produced in the form of grits made up of different components (see Table 15). Electrode alloys are put out in the form of lengths of electrode wire with a coating of a special composition.

Metal Ceramic Hard Alloys

1. Chemical Composition and Properties

The chemical composition and the physical and mechanical properties of the metal ceramic hard alloys used in machine building are shown in Tables 12 and 13.

The structure of the VK-type metal ceramic hard alloys is two-phase: crystals of tungsten carbide cemented by a solid solution of the carbide in cobalt. The structure of the titanium-tungsten alloys (T5K10, etc.) is three-phase: crystals of tungsten carbide, a solid solution of the carbides of tungsten and titanium, and a solid solution of the carbides in cobalt.

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The significant properties of metal ceramic hard alloys are their magnetic saturation and coercive force.

The magnetic saturation is approximately proportionate to the cobalt content of the hard alloy. The coercive force depends on the dispersity of the alloy structure. The finer the structure, the higher the dispersity. The magnetic saturation of metal ceramic hard alloys ranges from 100 to 150 oersteds, and the coercive force is 170-250 oersteds.

As to the durability of tungsten and titanium-tungsten metal ceramic hard alloys in relation to the speed of cutting in machining steel, the durability of tungsten alloys decreases continuously with an increase in the cutting speed, while in the case of the titanium-tungsten alloys, there is a definite optimum speed (75-100 meters per minute) at which they have the greatest durability.

2. Use of Metal Ceramic Hard Alloys

Table 14 shows the recommended fields of use of various metal ceramic hard alloys.

3. Metal Ceramic Hard Alloy Products

The following items are made from metal ceramic hard alloys: for machining metal -- tips for cutting tools (GOST 2209-44) and drawing dies for drawing rods and tubes (GOST 2330-43); for mining -- tips for electric and other drills, and for coal-cutting machine bits. Nonstandard items are made by special order.

Fused Hard Alloys

The chemical composition of fused hard alloys is shown in Table 15; the composition of electrode coatings, in Table 16; the physical and mechanical properties of cast fused hard alloys, in Table 17; and the physical and mechanical properties of laminae built up with granular and electrode alloys, in Table 18.

Sormayt No 2 submits well to heat-treatment (hardening and tempering), which increases its hardness considerably. Heat-treatment of other fused hard alloys does not produce structural changes in them and has scarcely any effect on their properties.

1. Microstructure of Fused Hard Alloys

The structural components of stellites VK2 and VK3 (built-up and not built-up) are solid solutions of carbides of chromium and tungsten, as well as free chromium and tungsten in cobalt. With a low carbon content, the structure of the stellite is hypoeutectoid; with an average carbon content, it is eutectoid; and with a high carbon content, it is hypereutectoid, with free crystals of the carbides present along with the solid solution. Stellites with hypoeutectoid structure have maximum resilience and minimum hardness, while those with hypereutectoid structure have the opposite characteristics.

Sormayt No 1 (built-up and not built-up) has a hypereutectoid structure, with a marked excess of free carbides of chromium.

Sormayt No 2 (built-up and not built-up) has a hypoeutectoid structure (solid solution of carbides of chromium in iron and nickel).

Vokar (built-up lamina) consists of a solid solution of carbides in iron of varying concentration depending on the thickness of the built-up lamina and other factors.

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Stalinite (built-up lamina) consists of a solid solution of carbides of chromium and manganese in iron.

2. Chromium, Manganese and Stalinite Electrodes

The structure of the laminae built up with these electrodes may vary within wide limits, depending on such factors as the chemical composition and the thickness (weight) of the electrode coating.

The laminae built up with stalinite-coated electrodes may have austenitic, martensitic, or ledeburitic structure. To obtain a lamina with austenitic structure built up with stalinite-coated electrodes, it is necessary that the weight of the coating be equal to 15-18 percent of the weight of the entire electrode. Martensitic structure results when the weight of the coating is 20-25 percent of the total weight; and ledeburitic structure, when it is above 30 percent. The characteristic features of the built-up lamina are the following: austenitic -- great wear-resistance, hardness, and resilience; martensitic -- great hardness, increased friability, and diminished wear-resistance; ledeburitic -- very high friability; poor wear-resistance, porosity, and coarse fracture. The most important fields of use of fused hard alloys are shown in Table 19.

[Appended tables follow.]

Table 1. Mechanical Properties of Porous Sintered Iron

Density of the Compact (g/cc)	Properties of Sintered Iron: Tensile Strength (kg/sq mm)	Yield Point (kg/sq mm)
5.0	--	--
5.5	9-11	8-10
6.0	14-16	12-13
6.5	18-20	13-14

Table 2. Chief Properties of Metal Ceramic Materials

Material	Brinell Hardness	Tensile Strength (kg/sq mm)	Compression Strength (kg/sq mm)	Elongation (%)	Impact Strength (kg-m/sq cm)
Antifriction, with an iron base, with 20-25% porosity	30-50	12-15	50-60	0-1	6-10
The same, with a copper base	25-30	7-10	45-60	0-1.5	10-13
Dense, with an iron base	65-85	28-30	65-80	20-25	10-11
Friction, with a copper base	30-45	8-12	40-60	0-1	--

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Table 3. Technical Description of the Most Important Types of Porous Bearings

Bearing Material	Chemical Composition (%) Fe	Cu	Sn	Graphite	Specific Density (g/cc)	Porosity (%)	Tensile Strength (kg/sq mm)	Compression Strength (kg/sq mm)	Brinell Hardness
Iron-graphite (Voizit)	98-97	--	--	2-3	5.0-6.5	20-30	8-12	60-80	25-40
Bronze-graphite	--	90-86	8-10	2-4	5.5-6.5	18-20	6-8	35-40	15-30

Bearing Material	PV Value (kg-cm/sec)	Coefficient of Friction, on Steel, Without Lubrication	Coefficient of Linear Expansion (10^{-6} mm/m/$^{\circ}$C)
Iron-graphite (Voizit)	60-80	0.03-0.04	9-11
Bronze-graphite	25-40	0.03-0.04	12-17

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Table 4. Results of Tests* on Porous Bearings on Zaytsev's Machine

Bearing Material	P=25 kg/sq cm for 2 hrs: Temperature Increase ($^{\circ}$C)	P=25 kg/sq cm for 2 hrs: Coefficient of Friction	P=50 kg/sq cm for 10 hrs: Temperature Increase ($^{\circ}$C)	P=50 kg/sq cm for 10 hrs: Coefficient of Friction
Porous iron	24.5	0.018	40.7	0.013
Porous iron with 1.75% graphite content	25.6	0.026	33.8	0.016
Porous iron with 2% graphite and 7% copper	32.3	0.016	39.8	0.010
Babbitt B-83	26.8	0.057	33.1	0.033

*Tests were conducted at a speed of 10 meters per second, under a load. Lubricant was spindle oil 2.

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Table 5. Technical Descriptior of Friction Materials

Material	Chemical Composition (%)							Properties			
	Cu	Sn	Pb	Fe	Graphite	Asbestos	Si	Brinell Hardness	Porosity (%)	Coefficient of Friction, on Steel, Without Lubrication	(mm/hr)
Copper-base	60-75	5-10	6-15	--	4-8	Up to 1	Up to 1	25-40	2-5	0.3-0.4	0.08-0.1
Iron-base	--	--	5-10	80-86	Up to 7	Up to 2	--	40-60	2-5	0.4-0.8	0.1-0.12

Table 6. Properties of Metal Ceramic Contacts

Base	Specific Density (g/cc)	Electrical Conductivity (m/ohm x sq mm)	Brinell Hardness	Compression Strength (kg/sq mm)
Tungsten	9.5-14.5	25×10^{-4}-38×10^{-4}	60-160	60-130
Molybdenum	8.5-12.5	30×10^{-4}-40×10^{-4}	45-125	60-120
Silver	7.5-9.5	42×10^{-4}-58×10^{-4}	25-50	--

Table 7. Durability of Metal Ceramic and Copper Welding Contacts

Contacts	Number of Operations Before Breakdown, Under an Electrical Load of				
	5 KW	10 KW	15 KW	20 KW	25 KW
Copper	50,000	25,000	18,000	5,000	1,000
Copper-tungsten	300,000	150,000	75,000	12,000	2,500

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Table 8. Properties of Metal-Graphite Brushes

Brush	Graphite Content (%)	Brinell Hardness	Specific Electrical Resistance (ohm/sq mm/m)	Permissible Current Density (a/sq cm)*	Permissible Linear Speed (m/sec)	Normal Pressure (g/sq cm)
MG	Up to 1	6-12	0.05-0.1	25-30	20	120-150
MG-1	10-15	5-7	0.1-0.25	22-25	20	120-150
MG-2	15-20	4-6	0.2-0.4	22-25	25	120-150
MG-3	20-25	3-5	0.3-0.45	20-22	25	120-150
M-I	50	--	4-10	14	15	160-200
M-II	75	--	6-16	12	20	160-200

*Carbon and graphite brushes have a permissible current density of 5.5-7.5 a/sq cm.

Table 9. Description of the Most Important Types of Metal Ceramic Magnetic Materials

	Chemical Composition (%)							Physical Properties			
Material	Iron	Nickel	Cobalt	Aluminum	Silicon	Copper	Bakelite	Loss Coefficient for Eddy Currents	Coercive Force (oersteds)	Residual Induction (Gauss)	Initial Magnetic Permeability μ_0 (Gauss/oersted)
Carbonyl iron*	100	--	--	--	--	--	--	5×10^{-7}	0.08	6,000	3,300
Alnico**	78-41	14-20	5-27	3-12	--	0-7	0-8% of of the quantity of metal	--	500-600	3,000-4,000	--
Alni**	62-57	25-28	--	13-15	--	--		4.8×10^{-7}	450-580	3,500-4,000	--
Alsifer***	82.5	--	--	7.5	10.0	--		3.5×10^{-7}	12-25	--	10,000-15,000

Field of use:

* Cores of all types for a frequency of up to 100,000 kilocycles
** Magnets for instruments
*** High-frequency choke coils, trimmers, and cores for a frequency of up to 500-2,000 kilocycles

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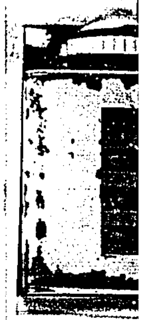

Table 10. Description of the Most Important Metal Ceramic Structural Materials

Material	Specific Density (g/cc)	Tensile Strength (kg/sq mm)	Yield Point (kg/sq mm)	Elonga-tion (%)	Brinell Hardness
Pure nonporous iron, sintered, (carbonyl)	7.8-8.0	20-32	--	28-40	56-80
Carbon steel with 0.2-0.3% C (with a 10% porosity)					
Annealed	7.0	27	20	8	60
Hammer-hardened	7.0	31	--	2.5	80
Hardened	7.0	39	--	1	250
Bronze (90% Cu, 10% Sn, with a porosity of about 5%)					
Annealed	7.9	27	16	13	62
Hammer-hardened	7.9	29	23	4	72
Pure copper (with 10% porosity)					
Annealed	8.0	27	14	17	55
Hammer-hardened	8.0	29	21	5	72
Stainless steel E Ya 1 (with 20% porosity), sintered and hardened	--	58	20	30	200
Brass (70% Cu, 30% Zn(	7.88	23	--	14	70

Table 11. Properties of Tungsten, Molybdenum, and Tantalum

Properties	W	Mo	Ta
Specific density (g/cc)	19-19.3	10-10.3	16.6
Melting point (^{o}C)	3,400±50	2,630±50	2,900±100
Tensile strength (kg/sq mm)	110-200	35-120	90-120
Relative elongation (for wire --%)	1-4	2-5	2-10
Brinell hardness	200-400	200-255	80-200
Coefficient of linear expansion at 25^{o}C	4.4×10^{-6}	5.2×10^{-6}	--
Heat conductivity at 20^{o}C (cal/cm/sec/^{o}C)	0.4	0.35	0.32
Specific electrical resistance (ohms/sq mm/m)	0.055	0.048	--

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Table 12. Chemical Composition of Metal Ceramic Hard Alloys, According to GOST 3282-47

	Chemical Composition of Alloy (%)						
	Approximate -- by Structural Components			By Elements			
Alloy	WC	TiC	Co	W	Ti	Co	C
VK3	97	--	3	91.05	--	3.0	5.95
VK6	94	--	6	88.3	--	6.0	5.70
VK8	92	--	8	86.37	--	8.0	5.63
VK10	90	--	10	84.5	--	10.0	5.50
VK15	85	--	15	79.80	--	15.0	5.20
T5K10	85	6	9	79.8	4.8	9.0	6.4
T5K7	88	5	7	82.6	4.0	7.0	6.4
T15K6	79	15	6	74.2	12.0	6.0	7.80
T30K4	66	30	4	62.0	24.0	4.0	10.0

Table 13. Physical and Mechanical Properties of Metal Ceramic Hard Alloys, According to GOST 3282-47

Alloy	Bending Strength (kg/sq mm)	Specific Density (g/cc)	Rockwell Hardness (A scale)	Red Hardness Temperature (°C)	Heat Conductivity (cal/cm/sec/°C)	Electrical Resistance (ohms/sq mm/m)
VK3	100	14.90	89.0	1,100-1,150	0.169	0.198
VK6	120	14.50	88.0	1,050-1,100	0.145	0.206
VK8	130	14.35	87.5	950-1,000	0.141	0.207
VK10	135	14.20	87.0	900-950	--	--
VK15	160	13.90	86.0	850-900	0.168	0.188
T5K10	115	12.20	88.50	1,100-1,150	--	--
T5K7	108	12.5	89.0	1,100-1,150	0.072	0.248
T15K6	110	11.0	90.0	1,200	0.065	0.399
T30K4	90	9.5	91.0	1,200	--	--

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Table 14. The Use of Metal Ceramic Hard Alloys

Alloy	General Description	Main Fields of Use
VK3	Very high wear-resistance and hardness, with low resilience	All types of processing of nonmetallic materials (glass, coal, stone, plastic, etc.)
VK6	Average resilience and wear-resistance	Semirough and finish grinding, milling, and reaming of cast iron and nonferrous metals
VK8	High resilience and durability, good resistance to impact and vibration	Rough grinding, milling, drilling, and other types of rough machining of cast iron and nonferrous metals
VK10 VK15	High resilience and wear-resistance	Drawing of steel and nonferrous metal rods and tubes (VK15 alloy is also used for drilling)
T5K10 T5K7	High resilience, good resistance to impact and vibration	Rough grinding and other types of rough machining of steel
T15K6	Less resilient than T5K7 and T5K10, but more wear-resistant	Semirough and finish grinding, high-speed grinding and milling of steel, cutting of threads, and reaming of holes
T30K4	Very high wear-resistance and hardness	High-speed grinding and boring of steel, with chips of small cross section

Table 15. Chemical Composition of Cast and Granular Fused Alloys

Alloy	Chemical Composition (%)								
	W	Co	Ni	Fe	Cr	Mn	C	Si	Impurities
Stellite VK2	13-17	47-53	Up to 2	Up to 2	27-33	1	1.8-2.5	1-2	1-1.5
Stellite VK3	4-5	58-62	Up to 2	Up to 2	28-32	--	1-1.5	2.5	1-1.5
Sormayt No 1	--	--	3-5	Remainder	25-31	1.5	1.5-3.3	2.8-4.2	1-1.5
Sormayt No 2	--	--	1.3-2.2	Remainder	13-17	1.0	1.5-2.0	1.5-2.2	1-1.5
Stalinite	No data	No data	No data	Remainder	16-20	13-17	8-10	Up to 3	1-1.5
Vokar	85-87	--	--	Up to 2	--	--	9-10	Up to 3	1-1.5

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Table 16. Composition of Electrode Coatings

Coating	Composition (%)									
	Ferro-chrome	Ferro-Manga-nese	Ferro-titanium	Stalinite	Boron Carbide	Graphite	Chalk	Fluorspar	Feldspar	Percent of Soluble Glass in Relation to Dry Coating
Chromium	70	--	--	--	--	15	15	--	--	5-8
Manganese	--	75	--	--	--	15	10	--	--	5-8
Stalinite	--	--	--	72	--	--	12	10	6	5-8
T-590	90	--	--	--	5	5	--	--	--	--
T-540	36.5	--	40.0	--	--	8.5	15.0	--	--	--
T-600	72.0	--	14.0	--	--	14.0	--	--	--	--

Table 17. Physical and Mechanical Properties of Cast Fused Hard Alloys

Alloy	Properties of Alloy				Properties of Single Built-Up Lamina		
	/Rockwell?/ Hardness /C scale?/	Specific Density /g/cc?/	Melting Point	Relative Wear*	Tensile Strength (kg/sq mm)	Rockwell Hardness (C scale)	Relative Wear*
Stellite VK 2	46-48	--	1,260	0.65-0.70	60-70	46-47	0.40-0.60
Stellite VK3	42-43	8.55	1,275	0.60-0.65	60-70	41-43	0.50-0.55
Sormayt No 1	49-54	7.4	1,275	0.55-0.70	35.0	49-50	0.61-0.65
Sormayt No 2	40-45	7.6	1,300	0.30-0.70	39-43	39-43	0.65-0.70

* The wear of mangenese wear-resistant steel G12 is equal to 1

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Table 18. Physical and Mechanical Properties of Laminae Built Up With Granular and Electrode Alloys (per single lamina)

Alloy	Rockwell Hardness (C scale)	Relative Wear*	Red Hardness (°C)
Granular			
Vokar	61-63	0.17-0.18	1,000-1,900
Stalinite	56-57	0.57-0.60	800-850
Electrodes with wear-resistant coating			
Chromium	55-58	0.8-0.9	850-900
Manganese	52-56	0.95-1.0	700-750
Stalinite	54-56	0.58-0.62	750-800

* Wear of manganese wear-resistant steel G12 is equal to 1

Table 19. Recommended Fused Hard Alloys

Causes of Wear	Conditions of Work	Recommended Fused Hard Alloys
Impact and shock	Rough mechanical wear (crusher jaws, excavator teeth, millstones for disk mills, grab crane jaws, etc.)	Vokar, stalinite, electrodes (with wear-resistant coating) Sormayt No 1 and 2
	Careful machining and heat-treatment are required after fusing on (punches for riveting, etc.)	
Attrition and impact	Hot cutting of metals (trimming dies and punches, blades for shears, trimming rings, etc.)	Sormayt No 1 and 2
	Cold cutting of metals (trimming dies and punches, blades for shears, blanking dies, punches, etc.)	Sormayt No 1 and 2
Attrition (for the most part)	Rough wear (screw-conveyer blades, plowshares, exhaust-fan blades, rollers for roll tables, etc.)	Vokar, stalinite, coated electrodes
	Machining is required after fusing on (shaft and axle journals, bearing bushings, measuring instruments, feed rollers)	Sormayt No 1 and 2

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Causes of Wear	Conditions of Work	Recommended Fused Hard Alloys
Erosion and corrosion	Corrosion, no strong mechanical effects, and at moderate temperatures (steam turbine blades)	Stellites, sormayt No 1 and 2
	Corrosion and mechanical effects, at high temperatures	Stellites, sormayt No 1, and stalinite

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